Wahler Associates
Geotechnical and Water Resources Engineering

February 20, 1987
Project SCV-124C

Santa Clara Valley Water District
5750 Almaden Expressway
San Jose, California 95118

Attention: Mr. G. Thomas Dean

Subject: Geotechnical Evaluations
Anderson Dam Spillway
Santa Clara County, California

References: Geotechnical Investigation Report titled "Leroy Anderson Dam Spillway Enlargement" by Wahler Associates, dated February 1984.

Plans titled, "Modifications to Leroy Anderson Dam and Spillway", prepared by Tudor Engineering Company, dated August 1, 1986.

Gentlemen:

In accordance with your authorization, we have performed the additional geotechnical studies in regard to the proposed final design for the modifications to Anderson Dam and Spillway. The studies were requested in response to two specific questions raised during an earlier review of several items submitted by Tudor Engineering; specifically the impact of the new fill on the stability of the downstream slope of the dam, and the slope stability below the left training wall at the spillway. The work was authorized by the District in a letter dated January 23, 1987.

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A. PURPOSE AND SCOPE OF SERVICES

1. Anderson Dam - Downstream Slope

The purpose of our work was to evaluate the impact of the proposed fill on the downstream slope stability. The stability of the modified downstream slope was evaluated by analyzing the slope at the maximum section. The following parameters were used in the analyses:

- One assumed phreatic line, corresponding to normal maximum reservoir.
- Two rockfill strengths, as assumed previously by Wahler (1977).
- Properties of other embankment materials were as determined previously by Wahler Associates (1977).
- Pseudostatic coefficients of 0, 0.1, and 0.2.

The results of the analyses are presented in this letter report.

2. Anderson Dam Spillway - Left Training Wall

The purpose of our work was to evaluate the stability of the natural slope adjacent to the proposed left training wall. Specifically, our work included:

- Three seismic refraction lines, one each at the existing access ramp, at the end of the training wall, and downslope from the end of the training wall.
- Drilling one exploratory boring on the access ramp (near the training wall centerline) to a depth of 40 feet.
- Laboratory tests including classification, triaxial shear, moisture content and dry density tests.
- Slope stability analyses under both static and seismic conditions as simulated by using a pseudostatic coefficient of 0.1 and 0.2.

B. ANDERSON DAM -DOWNSTREAM SLOPE

1. Design Criteria

The following information was used to develop the embankment section for analysis. The original dam was built to a design crest elevation of 640, with a crest width of 40 feet. However, current aerial topography shows the crest as low as Elevation 637.5, with a width of 40 feet. The design calls for stripping the crest to a depth of about 1-foot to expose competent impervious core material.

The new crest elevation is to be 644.8, with a width of 26 feet, except for a 40-foot wide turn-around segment near the center of the dam. We conservatively assumed this maximum width coincided with the maximum section for analysis. The section used for analysis is shown on Figure 1. Riprap and filter zones are to be included in the new section. However, for simplicity of stability analysis these zones were not defined as distinct from the adjacent zones. In our opinion, this assumption will have a negligible effect on the calculated stability.

Stability analyses were conducted for steady-state seepage conditions at normal maximum pool (at Elevation 625), and an estimated phreatic surface as shown on Figure 1.

The range of strengths used for the existing rockfill shell material were the same as previously used by Wahler (1977). For the new rockfill, the same friction angles were assumed, but the assumed cohesion intercept was reduced to zero based on the likelihood of there being very little fines in this material. For core material, we assumed the same strengths for both existing and new material. However, for the analysis, we followed the method recommended by the U.S. Army Corps of Engineers for long-term stability in their manual entitled, Engineering and Design, Stability of Earth and Rock-fill Dams, Engineering Manual No. EM 1110-2-1902, dated April

1, 1970, using the average of effective and total stress strengths in the stress range where the effective strength exceeds the total strength. This approach is empirical in nature and reflects experience that when analyses are made using certain assumptions regarding failure surface, given methods of statics, and results from certain types of tests interpreted in certain ways neither gross shear failure nor excessive deformations occur. Using this form of analysis, the Corps recommended minimum factors of safety of 1.4 for long-term conditions and 1.0 for earthquake loading. A summary of strengths used is given on Figure 1.

The critical failure surface was assumed to pass through the toe of the slope. We also analyzed stability with the failure surface passing through the toe of the new fill for the lower (and therefore more critical) of the two rockfill strengths.

2. Methods of Analysis

Conventional methods of limit equilibrium stability analysis to determine factors of safety against sliding using circular arc failure surfaces formed the basis of stability studies. The slope was computer-analyzed for circular arc failure modes using both the Fellenius method of slices and Bishop's modified method. These methods incorporate, as basic input data, the geometry of the embankment slope, internal zones, and the foundation, unit weight and shear strength properties of the embankment and foundation materials, and the distribution of internal water forces. After a failure surface has been assumed, the soil mass above the sliding surface is divided into a series of vertical slices. Forces acting on each slice include the earth pressures on its sides, water pressure on its sides and bottom, effective earth pressures with associated friction acting on the assumed sliding surface, and cohesion along the sliding surface. Various trial failure surfaces are analyzed until a minimum factor of safety is obtained for the case being studied.

The Fellenius method of slices is based on overall static moment equilibrium but does not consider the influence of side forces between slices. The factor of safety is calculated by comparing the moment of resistance offered by the cohesion and friction along the sliding surface to the moment of the driving force about the center of the assumed circular arc failure surface. The Bishop's modified method is a slightly more rigorous approach in which vertical equilibrium of the individual slices and overall moment equilibrium are satisfied. Side forces are included in the Bishop's analysis by using the simplifying assumption that they act only in a horizontal direction. Like the Fellenius method, factors of safety are obtained by comparing the resisting and driving moments.

These two computational methods were performed by computer analysis. The computer program STABR, developed at the University of California at Berkeley in 1972, was used to perform the stability analyses. The program performed automatic searches of different potential failure arcs to determine the most critical surface having the lowest factor of safety for the condition being analyzed.

3. Results of Analysis

The stability analysis results for the various strengths considered are presented on Figure 1. Our analysis indicates that the reduction in the factor of safety as a result of the new fill being added is no more than a few percent, and that in every case, the downstream slope factor of safety remains well above normally accepted minimums.

C. LEFT TRAINING WALL

1. Site Geology

a. General - This description of site geology is based upon field exploration performed as part of this study and a review of the geotechnical investigation for the spillway enlargement performed by Wahler Associates (1984). The field exploration consisted of one exploration drill hole and seismic refraction surveys. The site geology and location of the exploration are shown on Figure 2. A geologic section is shown on Figure 3. Drill hole logs and the seismic refraction survey profiles are included in Appendix A of this report. A more detailed study of the spillway area was performed by Wahler Associates in late 1983 and presented to the Santa Clara Valley Water District in a report entitled "Leroy Anderson Dam Spillway Enlargement", dated February 1984.

b. Bedrock Unit - Serpentine comprises the bedrock underlying the proposed left training wall. At and near the surface, the serpentinite is in large part crushed or sheared and soil-like with minor rock-like zones. The soil-like serpentinite is weak to soft and typically is grayish, yellow-green. The rock-like zones are medium-brown with some iron straining and consist of hard blocks and cobbles in soil-like matrix, or closely fractured weak masses.

The training wall is underlain by soil-like serpentinite to depths varying from 25 to 40 feet below the present ground surface. Soil-like serpentinite was encountered to 40 feet in hole DH-1-87, which is consistent with the absence of an intermediate (or higher) velocity material in SR-1 (Table 1). Intermediate velocities, indicating rock-like material as described above, were obtained downslope from seismic line SR-1 in seismic lines SR-2 and SR-3 at depths ranging from 13.7 to 35.4 feet. Downslope from the end of the training wall, the indicated depth to rock-like serpentinite is on the order of 25 feet.

c. Surficial Deposits - The only surficial deposit at the left training wall is fill placed during construction of the existing dam and spillway. In DH-1-87, the fill was about 4 feet thick and consisted of gravelly silty sand. The fill was not easily differentiated from the underlying bedrock, because it was derived from that same material excavated at the site during construction. The 1984 study by Wahler Associates shows the fill increases in thickness to at least 20 feet beneath the existing embankment near the proposed training wall.

2. Slope Stability

The stability of the natural slope adjacent to the left training wall was evaluated based upon the results of our field exploration and laboratory tests program. The slope analyzed also included a proposed fill that will support an access road to the spillway. The slope was analyzed for two long-term conditions, full reservoir (water surface at Elevation 625), partial reservoir (water surface at Elevation 575) and for seismic conditions. In all cases, the wall was represented by including the wall foundation pressure at the top of the slope. The foundation pressure of 5,000 psf was furnished by Tudor Engineering. The analyses were generally performed as described in Section B.2 of this report.

The strength parameters used in the analyses reflect laboratory test results, field observations, and the velocities obtained in the seismic refraction survey. The critical surfaces develop within the shallow rock in the top 25 to 30 feet. Failures through the stronger (as evidenced by the higher seismic refraction velocities), deeper, rock yielded higher safety factors than those shown on the following table.

Description	Friction Angle (Degrees)	Cohesion (psf)
Proposed Ramp Fill	35 (assumed)	100 (assumed)
Slope Materials		
a. Static	38	330
b. Pseudostatic	33	330

The following safety factors were obtained in the analyses:

	Pseudostatic Coefficient	Full Reservoir (W.S. Elevation 625)	Partial Reservoir (W.S. Elevation 575)
Long-term	0	2.30	2.02
Earthquake	0.1	1.34	1.44
Earthquake	0.2	1.08	1.08

The safety factors are equal to or exceed the minimum recommended by the Corps of Engineers of 1.4 for long-term conditions and 1.0 for earthquake loading. Therefore, it appears that no modification to the proposed design is warranted from a slope stability standpoint.

The conclusions and professional opinions presented herein were developed by Wahler Associates in accordance with generally accepted geotechnical engineering principles and practices. This warranty is in lieu of all other warranties, either express or implied.

We trust this report presents the information that you presently require. If you have any questions, please feel free to call us.

Very truly yours,

WAHLER ASSOCIATES

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Principal
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RCE No. 28021, California

KVR:JIL:e

cc: Addressee (5)

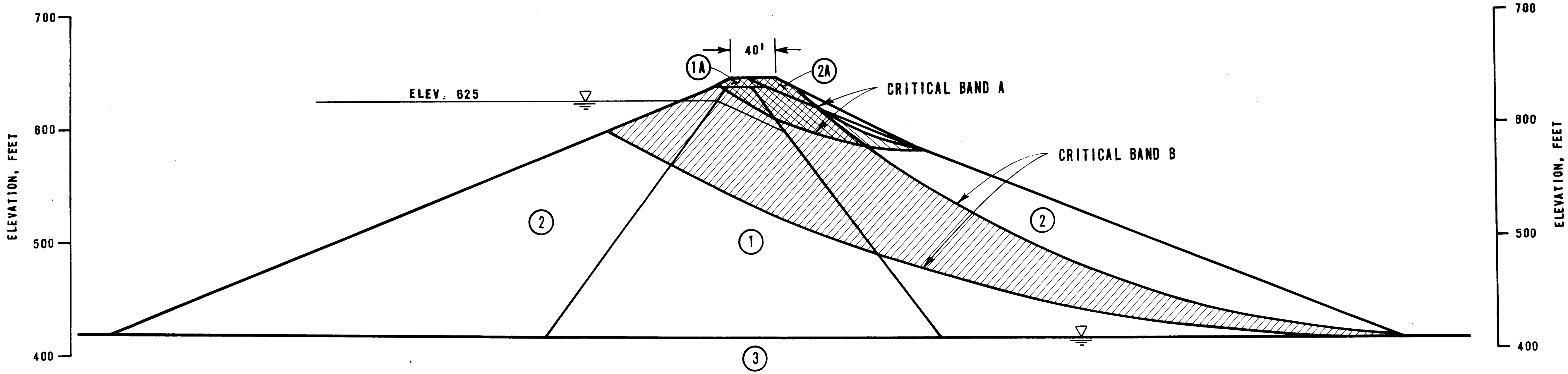
TABLE 1

SUMMARY OF SEISMIC REFRACTION SURVEY RESULTS[1]

Seismic Line No.	Average Upper Layer Velocity FPS	Average Second Layer Velocity FPS	Second Layer Depth, ft. Station A	Second Layer Depth, ft. Station B	Average Third Layer Velocity FPS	Third Layer Depth, ft. Station A	Third Layer Depth, ft. Station B
SR-1	1,400	2,310	9.9	9.7	---	---	---
SR-2	1,260	2,110	5.2	5.2	5,680	27.0	26.0
SR-3	1,030	2,150	3.9	3.5	4,360	35.4	13.7

[1] See Appendix A for seismic refraction survey profile.

[2] See Figure 2 for locations of seismic lines SR-1, SR-2, and SR-3.

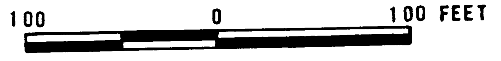


MAXIMUM SECTION

SOIL PARAMETERS USED IN STABILITY ANALYSES								
MATERIAL DESIGNATION	DESCRIPTION	UNIT WEIGHT (pcf)	TOTAL STRESS		EFFECTIVE STRESS		USED FOR ANALYSES	
			COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)	COHESION (psf)	FRICTION ANGLE (degrees)
①	EXISTING CORE	130	800	17	800	28	800	22.5
(1A)	PROPOSED NEW CORE	130	800	17	800	28	800	22.5
②	EXISTING SHELL	140	----	----	250	35-40	250	35-40
(2A)	PROPOSED NEW SHELL	140	----	----	0	35-40	0	35-40
③	FOUNDATION	150	----	----	20,000	0	20,000	0

SUMMARY OF STABILITY ANALYSES RESULTS				
CRITICAL BAND IDENTIFICATION	SHELL FRICTION ANGLE (degrees)	FACTOR OF SAFETY		
		SEISMIC COEFFICIENT (g)		
		0	0.1	0.2
A	35	1.92	1.49	1.21
A	40	2.24	1.70	1.34
B	35	1.87	1.50	1.24

SCALE



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ANDERSON DAM

PALO ALTO ● CALIFORNIA

STABILITY ANALYSES - DAM RAISE

PROJECT NO.	DATE	FIGURE NO.
SCV-124C	FEBRUARY 1987	1

EXPLANATION

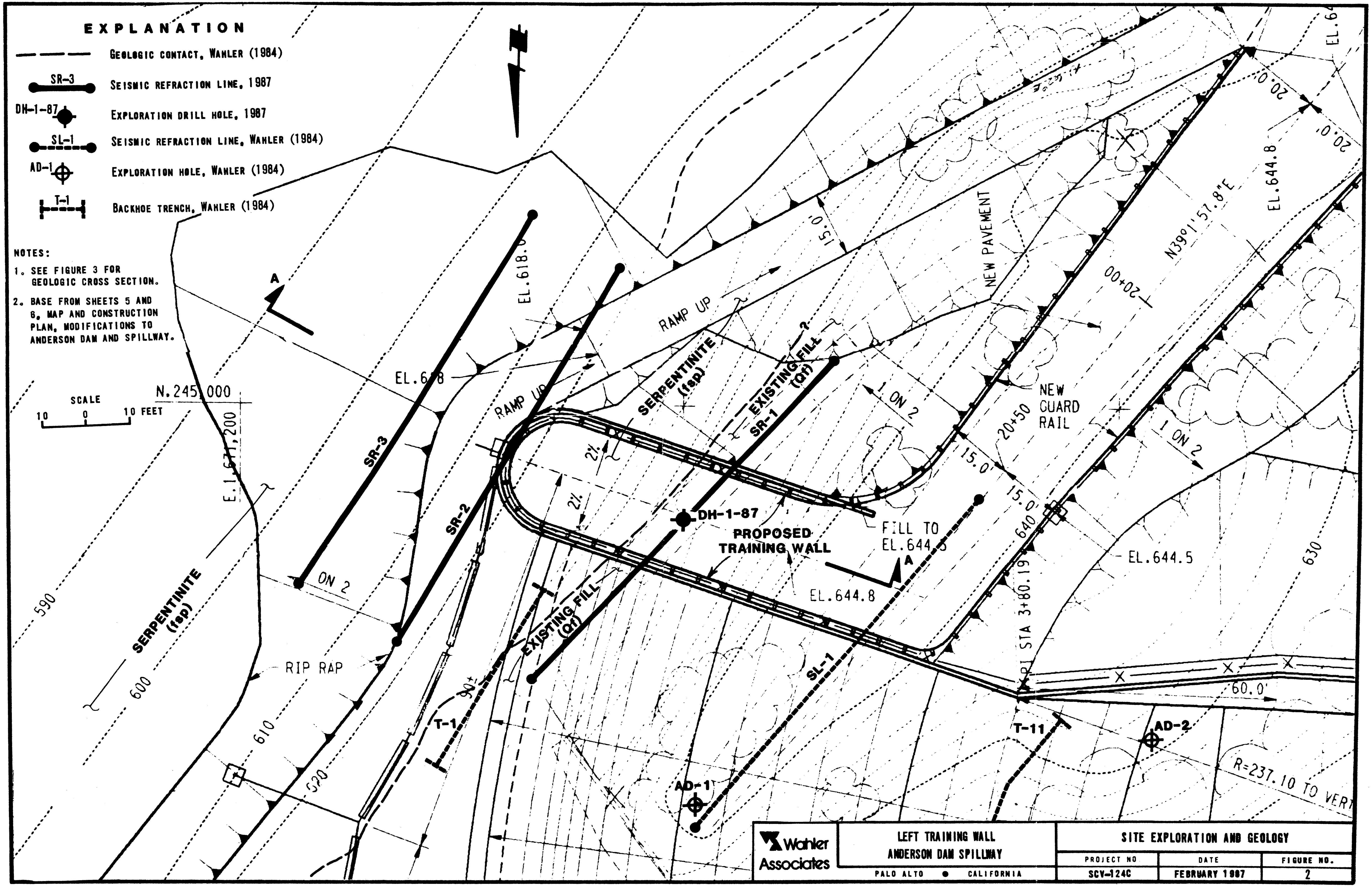
— — —	Geologic contact, Wahler (1984)
SR-3	Seismic refraction line, 1987
DH-1-87	Exploration drill hole, 1987
SL-1	Seismic refraction line, Wahler (1984)
AD-1	Exploration hole, Wahler (1984)
T-1	Backhoe trench, Wahler (1984)

NOTES:

1. SEE FIGURE 3 FOR GEOLOGIC CROSS SECTION.
2. BASE FROM SHEETS 5 AND 6, MAP AND CONSTRUCTION PLAN, MODIFICATIONS TO ANDERSON DAM AND SPILLWAY.

SCALE

10 0 10 FEET



LEFT TRAINING WALL
ANDERSON DAM SPILLWAY

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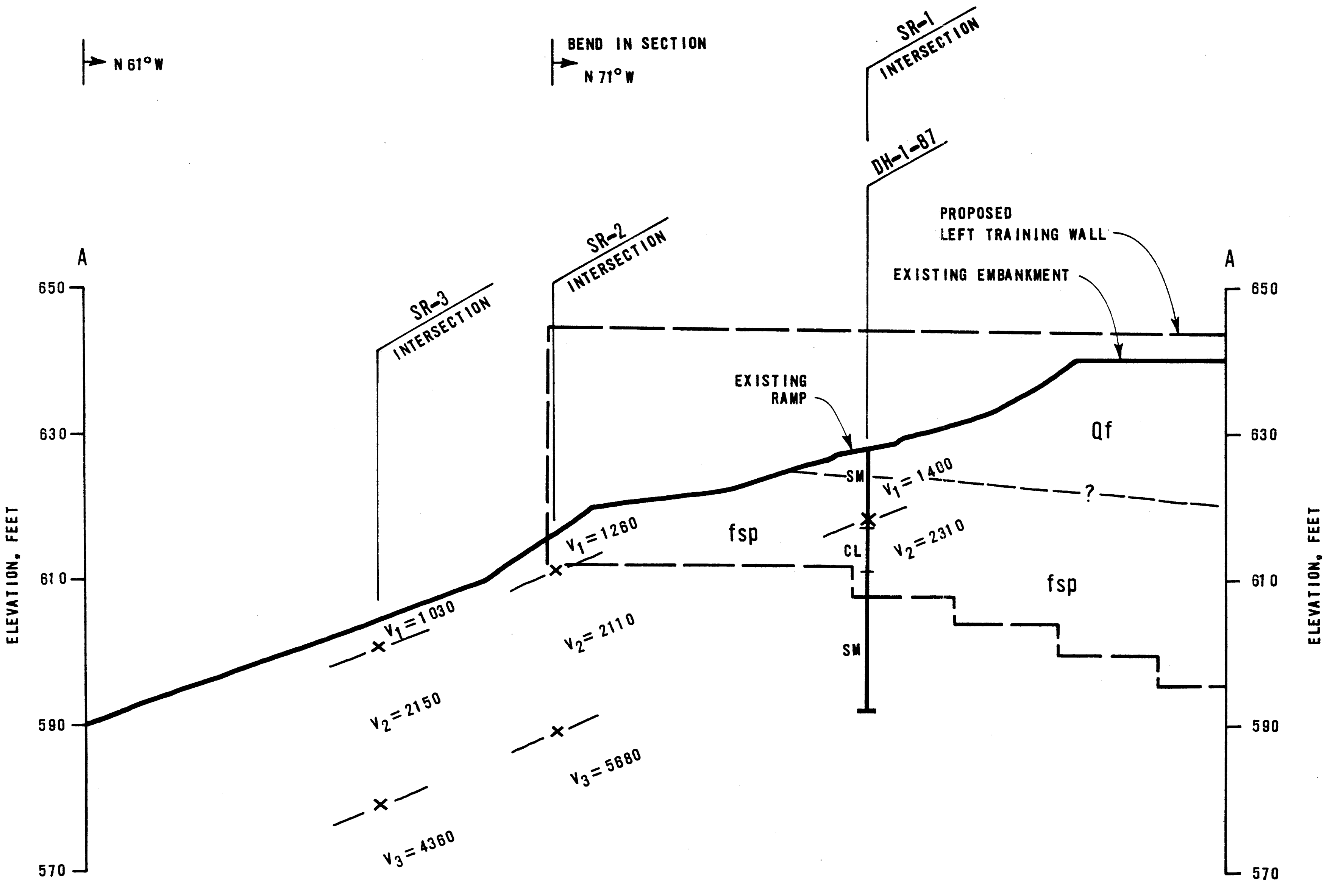
SITE EXPLORATION AND GEOLOGY

PROJECT NO	DATE	FIGURE NO.
SCV-124C	FEBRUARY 1987	2



EXPLANATION

GEOLOGIC UNITS

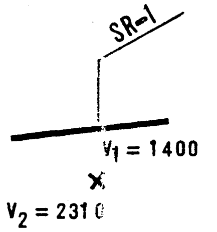
QUATERNARY

Qf	FILL: GRAVELLY SILTY SAND, DERIVED FROM SERPENTINE; MEDIUM BROWN

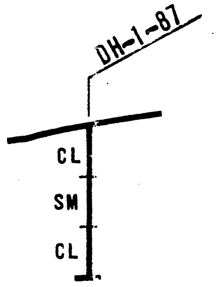
MEZOZOIC

fsp	SERPENTINE: UNDIFFERENTIATED, CRUSHED TO MODERATELY FRACTURED, WEAK, DENSE, YELLOW GREEN.

SYMBOLS



SEISMIC REFRACTION LINE WITH VELOCITIES IN FEET PER SECOND.



DRILL HOLE WITH SOIL CLASSIFICATION

SCALE

20 0 20 FEET

HORIZONTAL = VERTICAL

Wahler Associates	LEFT TRAINING WALL ANDERSON DAM SPILLWAY PALO ALTO • CALIFORNIA	GEOLOGIC CROSS SECTION A–A		
		PROJECT NO.	DATE	FIGURE NO.
		SCV-124C	FEBRUARY 1987	3

APPENDIX A

APPENDIX A

FIELD INVESTIGATION

The field investigation was performed on January 28 and 29, 1987 and included an exploratory boring and seismic refraction surveys.

A. DRILLING

One hole was drilled to a depth of 40 feet to develop a subsurface profile, assist in interpreting the subsurface profile, and obtain samples for laboratory testing. A rotary drill rig was used to drill the hole. Drilling services were provided by Pitcher Drilling Company of Palo Alto, California, using a Failing 750 drill rig. Continuous samples were obtained by using a pitcher barrel sampler.

The drilling was performed under the observation of a Wahler Associates' engineering geologist. A continuous boring log was maintained, showing soil conditions, sample depths and other data. The location of this drill hole is shown on Figure 2 entitled "Site Exploration and Geology". The soils were classified in accordance with the Unified Soil Classification System. Figures A-1 and A-2 entitled "Key for Soil Exploration Logs" and "Key for Rock Core Logs", respectively, give a detailed explanation of symbols and terms used.

The drill hole was backfilled with a concrete slurry upon completion.

B. SEISMIC REFRACTION SURVEY

A shallow seismic refraction survey was performed by Wahler Associates to develop seismic velocities of near-surface rock units in the proposed spillway expansion area. This survey provided a qualitative comparison with the data and samples obtained from the drill hole, in addition to providing an assessment of the rock quality based on the velocities. Seismic velocities can also be correlated with rippability using published data (Caterpillar, 1978).

A Bison signal enhancement seismograph, Model 1570C, was used. Travel times for first arrival seismic waves were recorded at 10-foot increments out to 100 feet from the geophone location. All seismic lines were recorded in both directions (forward and reverse) to eliminate velocity errors caused by dipping refractors. A total of 3 seismic lines were run. Graphical representations of the field data obtained from the seismic lines are presented in this appendix. A summary of the seismic velocities derived from this data is presented in Table 1.

BORING LOCATION Anderson Dam Spillway			**GROUND EL.** 628 (Base map)
DEPTH/ELEV. WATER Not determined	**DRILL CONTRACTOR** Pitcher Drilling		**TOTAL DEPTH** 40.0
DRILL RIG Failing 750	**BORING DIA.** 5.0"	**DATE DRILLED** 1-29	**LOGGED BY** P.T.L

SOIL CLASS.	DESCRIPTION	DEPTH	SAMPLE NO.	PR / RQD	REC.	MODE	REMARKS
SM	FRANCISCAN COMPLEX 0.0 - 11.0 *GRAVELLY SILTY SAND: Mod. brn (5YR 4/4); ~20% fines, non plastic, quick dilatancy; ~60% sand, fine- to coarse-grained, moderately graded, moderate hardness, serpentine frags, Fe coatings; ~20% gravel, fine (sporatically coarse); non cemented, disturbed structure; slightly pervious; lacks organics; medium dense; moist.	0.0				AD	Drillers arrived on site at 8:00 AM, leveled rig, drilling 8:47 Ron Hollingstad - Driller Harry McNight - Helper
		2.0					Augering to 3.5', set casing, set up mud tub, started rotary.
		4.0	PB-1		2.3 / 2.5	RD	9:05 / 9:21 3.5' 9:24 / 9:27 4.0' tricone to start hole. * Log data is based on field reconnaissance and additional enhouse inspection.
	*Weathered Serpentine to 40.0' 4.0-6.5' streaks of grayish yel. grn (5GY 7/2), shear zones, slightly clayey	6.0	PB-2		2.1 / 2.5		9:30 / 9:35 6.5 6.5 - 7.0 soft 7.0 - 8.5 hard 8.5 - 9.0 soft drilling return getting low
	6.5-9.0' more clayey alteration, highly fractured	8.0					9:41 / 9:45 9.0'
	9.0-11.5' highly fractured	10.0	PB-3		1.6 / 2.5		added Super-Gel X to mud tank and cleaned hole with tricone. 9:48 / 10:05 11.5
CL	11.0 - 40.0' SILTY SANDY CLAY Grayish yel grn (5GY 7/2) mottled with mod. yel. brn (10YR 5/4); ~70-80% fines, med. to slight plasticity, low toughness, ~20-30% sand, fine- to medium-grained, angular, serpentine frags, some Fe coatings, non cemented, deformed structure, low perviousness, no odor or organics; medium dense, moist.	12.0	PB-4 PB-5		0.5 / 1.5 1.2 / 1.2		11.5 - 14.0 mostly sluff in PB-4, 10:08 / 10:16 13.0 1.0' of PB-5 is sluff from PB-4 10:16 / 10:25 14.2
		14.0	PB-6		2.3 / 2.3		losing return, added more gel, H_2O now really thick.
SM	16.5 - 17.5 silty sand: moderate brown; ~25% fines, non plastic; ~75% fine- to coarse-grained sand, angular shaley frags; Fe coatings; dense; wet.	16.0	PB-7		1.0 / 1.0		10:27 / 11:00 16.5' 11:03 / 11:59 17.5'
CL	~16.5 - 20.0' getting more clayey and altered, slight plasticity.	18.0	PB-8		1.6 / 2.5		17.5' cleaning hole w/tricone and washing, thinning mud 12:04 20.0'
		20.0					

Wahler Associates

LEFT TRAINING WALL
ANDERSON DAM SPILLWAY

EXPLORATION BORING LOG

PROJECT NO. SCV 124.C

SHEET NO. 1 OF 2

BORING NO. DH-1-87

BORING LOCATION		GROUND EL.
DEPTH/ELEV. WATER	DRILL CONTRACTOR	TOTAL DEPTH
DRILL RIG	BORING DIA. / DATE DRILLED	LOGGED BY

SOIL CLASS.	DESCRIPTION	DEPTH	SAMPLE NO.	PR / RQD	REC.	MODE	REMARKS
CL	11.0-40.0' SILTY SANDY CLAY: (cont.) 22.4-26.2' material is more rock-like; blocky structure; Fe staining, dark gray brown.	20.0	PB-9		2.1 2.4	RD	Drilling is now smooth but stiff 12:16 20.0' 21.0' drilling is hard, soft, hard
		22.0					12:21 12:35 22.4'
		24.0	PB-10		0.9 2.6		12:40 12:54 25.0'
	~25.0-25.6' hard SHALEY, structure preserved.		PB-11		1.2 1.2		~25.6 drilling very hard but smooth
CL	~26.2-28.7' clayey sand, grayish green.	26.0	PB-12		1.9 2.5		1:10 1:20 26.2' added more Super-Gel
	~28.7-31.2' more clayey, moderate plasticity, yellowish	28.0	PB-13		0.9 2.5		1:33 1:37 28.7' ~29.0 drilling getting easier.
		30.0					1:51 2:01 31.2'
		32.0	PB-14		0.9 2.5		
	33.7-38.3' more blocky, rock-like.	34.0	PB-15		0.8 2.5		2:10 2:17 33.7' ~38.0' drill grinding.
	~36.0' reduction in clay, more shaley. more gray to blackish	36.0					2:21 2:30 36.2'
	~38.0' more shaley, reduction in fracturing, trace of clay, brn Fe staining.		PB-16		1.7 2.1		40.0' Terminated boring, backfilled with cement/cutting slurry to surface.
CL	40.0' greenish-gray, sandy clay Bottom hole 40.0'	38.0 40.0	PB-17		1.7 1.7		2:36 2:48 38.3 2:52 40.0'

DATA ON THIS LOG ARE AN APPROXIMATION OF THE GEOLOGIC AND SUBSURFACE CONDITIONS BECAUSE THE INFORMATION WAS OBTAINED FROM INDIRECT, DISCONTINUOUS, AND POSSIBLY DISTURBED SAMPLING NECESSITATED BY USE OF SMALL-DIAMETER HOLES. ROTARY AND WASH BORING HOLES HAVE FURTHER COMPLICATIONS IN THIS REGARD BECAUSE OF THE NEED TO USE DRILLING FLUID AND/OR CASING IN ADVANCING HOLES.

THIS LOG INDICATES CONDITIONS IN THIS HOLE ONLY ON THE DATE INDICATED AND MAY NOT REPRESENT CONDITIONS AT OTHER LOCATIONS AND ON OTHER DATES. ANY WATER LEVELS SHOWN ARE SUBJECT TO VARIATION.

THIS HOLE WAS LOGGED IN SUCH A WAY AS TO PROVIDE DATA PRIMARILY FOR DESIGN PURPOSES AND NOT NECESSARILY FOR THE PURPOSES OF SPECIFIC CONTRACTORS.

THE STRATIFICATION LINES OR DEPTH INTERVALS REPRESENT THE APPROXIMATE BOUNDARIES BETWEEN MATERIAL TYPES, AND THE TRANSITIONS MAY BE GRADUAL.

SOIL CLASSIFICATIONS SHOWN ON LOGS ARE FIELD CLASSIFICATIONS BASED ON THE UNIFIED SOILS CLASSIFICATION SYSTEM.

Wahler Associates

LEFT TRAINING WALL
ANDERSON DAM SPILLWAY

EXPLORATION BORING LOG

PROJECT NO. SCV 12.4 C

SHEET NO. 2 OF 2

BORING NO. DH-1-87

UNIFIED SOIL CLASSIFICATION SYSTEM (ASTM D-2487)

PRIMARY DIVISIONS			GROUP SYMBOL	SECONDARY DIVISIONS
COARSE GRAINED SOILS MORE THAN HALF OF MATERIALS IS LARGER THAN #200 SIEVE SIZE	GRAVELS MORE THAN HALF OF COARSE FRACTION IS LARGER THAN #4 SIEVE	CLEAN GRAVELS (LESS THAN 5% FINES)	GW	WELL GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES.
			GP	POORLY GRADED GRAVELS OR GRAVEL-SAND MIXTURES, LITTLE OR NO FINES.
		GRAVEL WITH FINES	GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURE. NON PLASTIC FINES.
			GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES. PLASTIC FINES.
	SANDS MORE THAN HALF OF COARSE FRACTION IS SMALLER THAN #4 SIEVE	CLEAN SANDS (LESS THAN 5% FINES)	SW	WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES.
			SP	POORLY GRADED SANDS OR GRAVELLY SANDS, LITTLE OR NO FINES.
		SANDS WITH FINES	SM	SILTY SANDS, SAND-SILT MIXTURES. NON-PLASTIC FINES.
			SC	CLAYEY SANDS, SAND-CLAY MIXTURES. PLASTIC FINES.
FINE GRAINED SOILS MORE THAN HALF OF MATERIAL IS SMALLER THAN #200 SIEVE SIZE	SILTS & CLAYS	LIQUID LIMIT IS LESS THAN 50	ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY.
			CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS.
			OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY.
	SILTS & CLAYS	LIQUID LIMIT IS GREATER THAN 50	MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILTS.
			CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS.
			OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS.
	HIGHLY ORGANIC SOILS		PT	PEAT AND OTHER HIGHLY ORGANIC SOILS.

DEFINITION OF TERMS

GRAIN SIZES

U.S. STANDARD SERIES SIEVE

200 50 16 4 3/4" 3" 6"

SILTS & CLAYS DISTINGUISHED ON BASIS OF PLASTICITY	SAND			GRAVEL		COBBLES	BOULDERS
	FINE	MEDIUM	COARSE	FINE	COARSE		

MOISTURE CONDITION (INCREASING MOISTURE ⟶)

DRY SLIGHTLY DAMP DAMP (PL) MOIST VERY MOIST WET (SATURATED) (LL)

KEY

SAMPLE NUMBER

SAMPLE CONTAINER:

BAG	B
JAR	J
SHELBY TUBE	S
DRIVE SAMPLER RINGS	R

MODE

METHOD OF ADVANCING HOLE:

DRILL

FLIGHT AUGER	AD
BUCKET AUGER	BA
SPIN AUGER	SD
HOLLOW STEM AUGER	HA
ROTARY DRILL	RD
CABLE TOOL	CT

SAMPLER

DRIVE	DR
PITCHER BARREL	PB
CORE	C
PUSH	P

RECOVERY

RECOVERY RATIO INDICATED BY A FRACTION:

$$\frac{1.2}{1.5} = \frac{\text{FOOTAGE RECOVERED}}{\text{FOOTAGE SAMPLED}}$$

REMARKS

INCLUDES DRILLING INFORMATION, E.G. WATER LEVEL, DATES.

REFUSAL: STOPPED BY MATERIAL TOO HARD FOR EQUIPMENT.

TERMINATED: SUFFICIENT INFORMATION OBTAINED.

ABANDONED: STOPPED BECAUSE OF DIFFICULTIES EXPLAINED ON LOG.

PENETRATION RESISTANCE (PR)
(RECORDED AS BLOWS/0.5 FOOT)

SANDS & GRAVELS

RELATIVE DENSITY	BLOWS/FOOT*
VERY LOOSE	0–4
LOOSE	4–10
MEDIUM DENSE	10–30
DENSE	30–50
VERY DENSE	OVER 50

CLAYS & SILTS

CONSISTENCY	BLOWS/FOOT*	STRENGTH †
VERY SOFT	0–2	0–¼
SOFT	2–4	¼–½
FIRM	4–8	½–1
STIFF	8–15	1–2
VERY STIFF	15–30	2–4
HARD	OVER 30	OVER 4

* Number of blows of 140 pound hammer falling 30 inches to drive a 2 inch O.D. (1-3/8 inch I.D.) Split-Barrel sampler (ASTM-1586 standard penetration test).

† Unconfined compressive strength in tons/sq ft. Read from a pocket penetrometer.

Wahler Associates	ANDERSON DAM	KEY FOR SOIL EXPLORATION LOGS	
		PROJECT NO.	FIGURE NO.
		SCV-124C	A-1

KEY TO COLUMNS

SOIL CLASSIFICATION: THE UNIFIED SOIL CLASSIFICATION SYMBOL IS USED WHEN APPROPRIATE, E.G. FOR POORLY INDURATED, SEVERELY WEATHERED, OR SOIL-LIKE MATERIALS.

DESCRIPTION: INCLUDES LITHOLOGY AND PHYSICAL CONDITION OF THE ROCK. THE DESCRIPTION IS FOR PURPOSES OF IDENTIFICATION, CORRELATION, AND INTERPRETATION. THE PHYSICAL CHARACTERISTICS ARE DESCRIBED BY USING THE TERMS DEFINED BELOW.

DEPTH: DEPTH IN FEET OR METERS AS INDICATED.

SAMPLE NO: X = BOX; WC = WRAPPED CORE. DEPTH INTERVAL IS SHOWN FOR EACH BOX.

PR/RQD: ROCK QUALITY DESIGNATION (RQD). SUM OF LENGTHS OF CORE >4"/ LENGTH OF RUN; EXPRESSED AS A PERCENT. PENETRATION RESISTANCE (PR) IS NOT APPLICABLE TO ROCK LIKE MATERIALS.

REC: RECOVERY RECORDED AS A FRACTION.

MODE: METHOD OF ADVANCING HOLE: AD = AUGER DRILLING; RD = ROTARY DRILLING; C = CORING; PD = PERCUSSION DRILLING.

REMARKS: INCLUDES DRILLING INFORMATION, E.G. DRILLING NOTE, WATER LOSS, DATES, ORIENTATION AND INCLINATION OF HOLE IF ANGLE HOLE.

DEFINITION OF TERMS

HARDNESS

VERY SOFT:	EASILY CRUMBLED OR DEFORMED BY HAND.
SOFT:	MAY BE BROKEN USING BOTH HANDS, OR IF PLASTIC, DEFORMED BY HAND. MAY BE CUT WITH DIFFICULTY WITH KNIFE. EASILY POWDERED WITH PICK, DULL THUD WHEN STRUCK WITH HAMMER.
MODERATELY HARD:	MAY BE SCRATCHED WITH KNIFE, TO SHALLOW DEPTH. DULL RING WHEN STRUCK WITH HAMMER.
VERY HARD:	CANNOT BE SCRATCHED WITH KNIFE. SHARP RING WHEN STRUCK.

STRENGTH

PLASTIC:	CAN BE DEFORMED BY HAND.
FRIABLE:	CRUMBLES BY RUBBING WITH FINGERS.
WEAK:	AN UNFRACTURED OUTCROP OF SUCH MATERIAL WOULD CRUMBLE UNDER LIGHT HAMMER BLOWS.
MODERATELY STRONG:	OUTCROP WOULD WITHSTAND A FEW FIRM BLOWS BEFORE BREAKING.
STRONG:	OUTCROP WOULD WITHSTAND A FEW HEAVY RINGING HAMMER BLOWS BUT WILL YIELD LARGE FRAGMENTS.
VERY STRONG:	OUTCROP WOULD RESIST HEAVY RINGING HAMMER BLOWS AND WILL YIELD WITH DIFFICULTY ONLY DUST AND SMALL FRAGMENTS.

WEATHERING

EXTENT	DECOMPOSITION	DISINTEGRATION	DISCOLORATION	FRACTURE CONDITION
SEVERE	MODERATE TO COMPLETE ALTERATION OF MINERALS, FELDSPARS ALTERED TO CLAY, ETC.	GENERALLY FRIABLE, BUT ROCK TEXTURE AND STRUCTURE ARE PRESERVED.	EXTENSIVE AND THOROUGH	ALL FRACTURES EXTENSIVELY COATED WITH OXIDES, CARBONATES, OR CLAY.
MODERATE	SLIGHT ALTERATION OF MINERALS, CLEAVAGE SURFACES LUSTERLESS AND STAINED.	MOST CEMENTATION IS AFFECTED; MAY BE LOCALLY FRIABLE.	MODERATE OR LOCALIZED AND INTENSE	THIN COATINGS OR STAINS.
SLIGHT	NO MEGASCOPIC ALTERATION OF MINERALS.	LITTLE TO NO EFFECT ON NORMAL CEMENTATION.	SLIGHT AND INTERMITTENT AND LOCALIZED	FEW STAINS ON FRACTURE SURFACES.
FRESH	UNALTERED, CLEAVAGE SURFACE GLISTENING.	CEMENTATION UNAFFECTED.	NO DISCOLORATION	NO STAINS

FRACTURING*

EXTENT	ENGLISH SIZE RANGE	METRIC SIZE RANGE
CRUSHED (MAY CONTAIN CLAY)	LESS THAN 0.05'	LESS THAN 1.5 cm.
INTENSELY FRACTURED	0.05' TO 0.1'	1.5 cm. TO 3 cm.
CLOSELY FRACTURED	0.1' TO 0.5'	3 cm. TO 15 cm.
MODERATELY FRACTURED	0.5' TO 1.0'	15 cm. TO 30 cm.
LITTLE FRACTURED	1.0' TO 3.0'	30 cm. TO 100 cm.
MASSIVE	3.0' AND LARGER	1 m. AND LARGER

FRACTURE COATINGS

EXTENT	THICKNESS
UNSTAINED OR CLEAN: NEARLY ALL SURFACE CLEAN	STAINED: NO PERCEPTIBLE THICKNESS
SMALL: COVERS LESS THAN 10% OF FRACTURE SURFACE	THIN: BARELY PERCEPTIBLE
MODERATE OR PATCHY: COVERS 10% TO 50% OF SURFACE	MEDIUM: UP TO 2 mm
EXTENSIVE: COVERS MORE THAN 50% OF SURFACE	THICK: OVER 2 mm

STRATIFICATION

STRATIFICATION (OR PARTING)	CROSS-STRATIFICATION	APPROXIMATE THICKNESS**	
		ENGLISH	METRIC
VERY THICK-BEDDED (-PARTED)	VERY THICKLY CROSS-BEDDED	OVER 3 ft.	OVER 1 m.
THICK-BEDDED (-PARTED)	THICKLY CROSS-BEDDED	1-3 ft.	30-100 cm.
MEDIUM-BEDDED (-PARTED)	MEDIUM CROSS-BEDDED	4-12 in.	10-30 cm.
THIN-BEDDED (-PARTED)	THINLY CROSS-BEDDED	1-4 in.	3-10 cm.
VERY THIN-BEDDED (-PARTED)	VERY THINLY CROSS-BEDDED	0.5-1 in.	1-3 cm.
LAMINATED (THINLY PARTED)	CROSS-LAMINATED	0.1-0.5 in.	0.3-1.0 cm.
THINLY LAMINATED (VERY THINLY PARTED)	THINLY CROSS-LAMINATED	LESS THAN 0.1 in.	LESS THAN 0.3 cm.

* JOINTS AND FRACTURES ARE TREATED THE SAME FOR THE PHYSICAL DESCRIPTION AND BOTH ARE REFERRED TO AS FRACTURES; SIZE RANGE REFERS TO SIZE OF PIECES.

** MASSIVE IF BEDS ARE OVER 10 ft. (3 m.) THICK.

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PROJECT NO.	FIGURE NO.	
SCV-124C	A-2	KEY FOR ROCK CORE LOGS

LOCATION Anderson Dam

LINE NO. SR-1

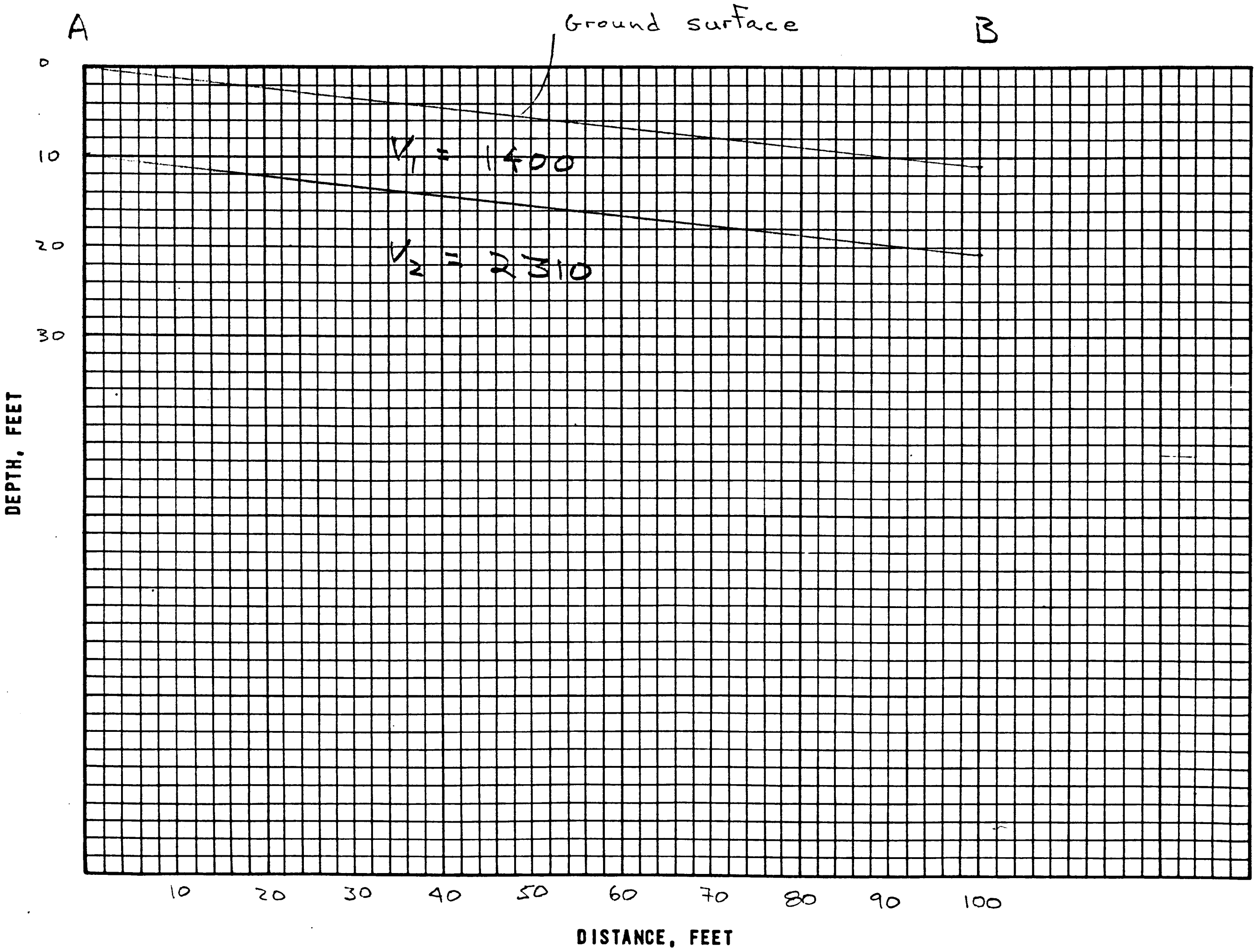
LINE BEARING (A TO B) N 42 E

PERFORMED BY P.J.L. & N.R.

LINE LENGTH 100 Ft.

DATE 1-28-87

V_1	AVERAGE VELOCITY LAYER 1	1400
W_2	DIP ANGLE LAYER 2	-0.66
V_2	AVERAGE VELOCITY LAYER 2	2310
HA_1	FIRST LAYER THICKNESS AT A	9.90
HB_1	FIRST LAYER THICKNESS AT B	9.70
W_3	DIP ANGLE LAYER 3	—
V_3	AVERAGE VELOCITY LAYER 3	—
HA_2	SECOND LAYER THICKNESS AT A	—
HB_2	SECOND LAYER THICKNESS AT B	—



LOCATION Anderson Dam

LINE NO. SR-2

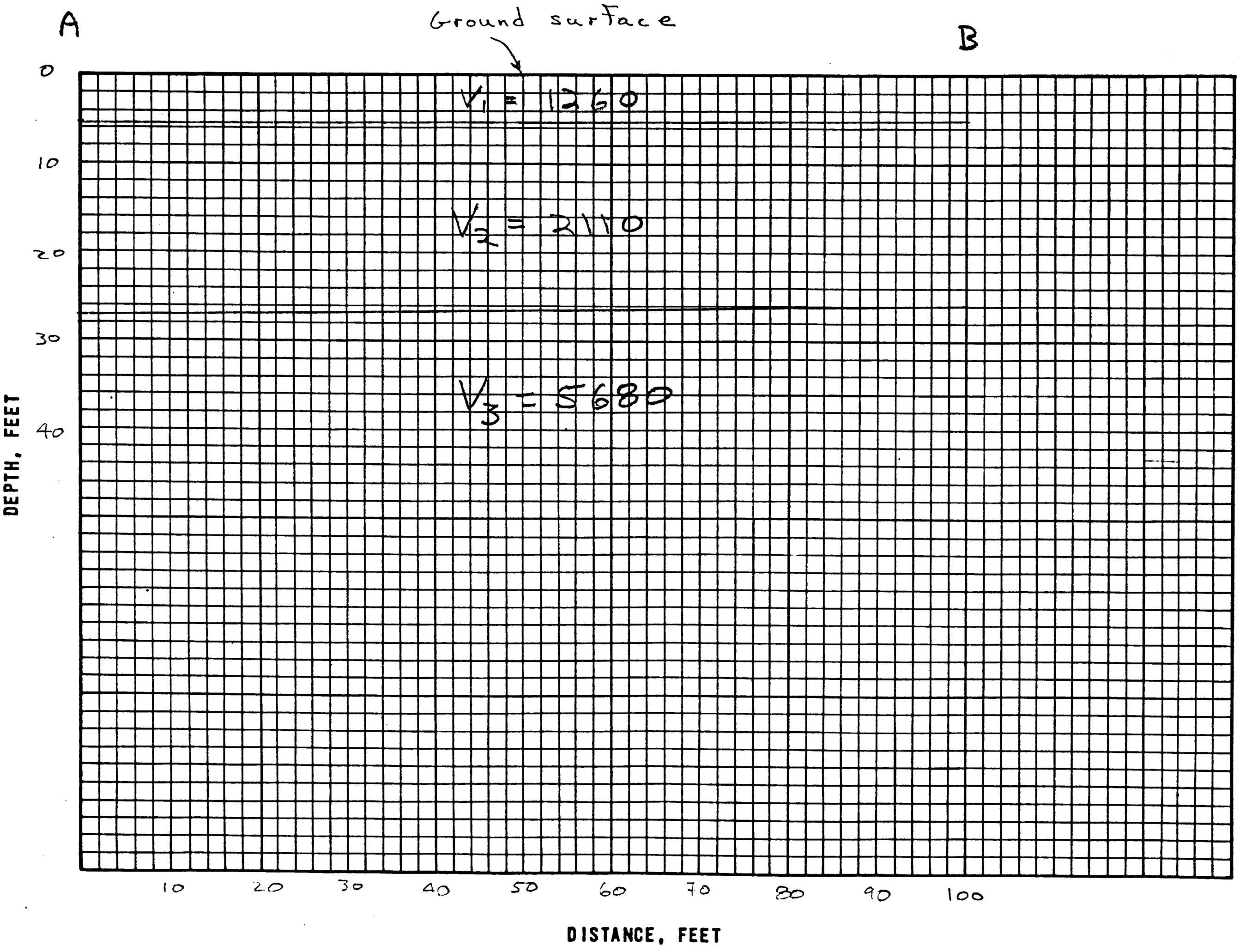
LINE BEARING (A TO B) N 31° E

PERFORMED BY P.J.L. & N.R.

LINE LENGTH 100 ft.

DATE 1-28-87

V_1	AVERAGE VELOCITY LAYER 1	1260
W_2	DIP ANGLE LAYER 2	6.90
V_2	AVERAGE VELOCITY LAYER 2	2110
HA_1	FIRST LAYER THICKNESS AT A	5.2
HB_1	FIRST LAYER THICKNESS AT B	5.2
W_3	DIP ANGLE LAYER 3	0.24
V_3	AVERAGE VELOCITY LAYER 3	5680
HA_2	SECOND LAYER THICKNESS AT A	21.8
HB_2	SECOND LAYER THICKNESS AT B	20.8



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LOCATION Anderson Dam

LINE NO. SR-3

LINE BEARING (A TO B) N 32° E

PERFORMED BY P.F.L. & N.R.

LINE LENGTH 100 Ft.

DATE 1-28-87

V_1 .... AVERAGE VELOCITY LAYER 1 1030

W_2 .... DIP ANGLE LAYER 2 .... -0.36

V_2 .... AVERAGE VELOCITY LAYER 2 2150

HA_1 .... FIRST LAYER THICKNESS AT A 3.9

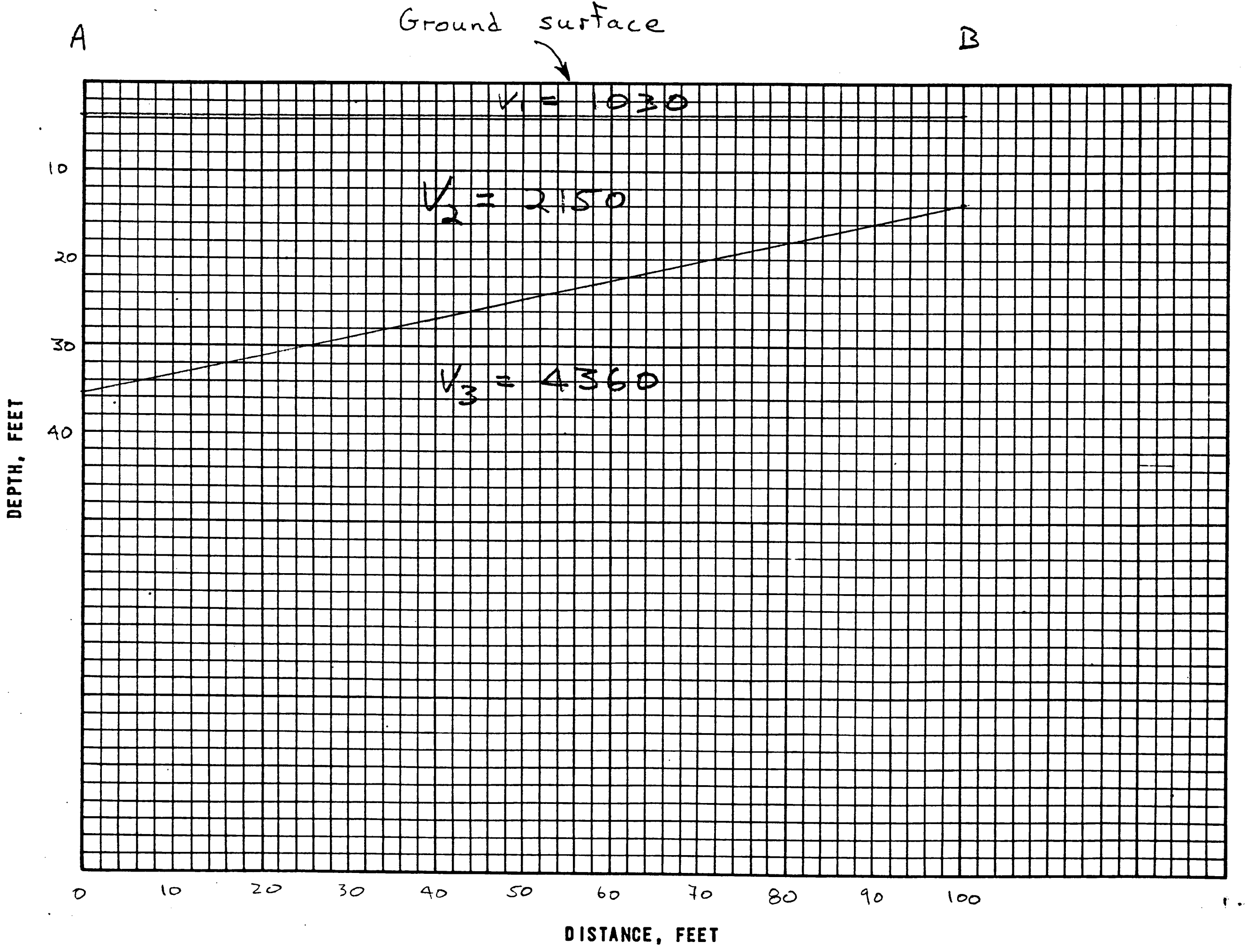
HB_1 .... FIRST LAYER THICKNESS AT B 3.5

W_3 .... DIP ANGLE LAYER 3 .... 13.79

V_3 .... AVERAGE VELOCITY LAYER 3 4360

HA_2 .... SECOND LAYER THICKNESS AT A 31.5

HB_2 .... SECOND LAYER THICKNESS AT B 10.2



APPENDIX B

APPENDIX B

LABORATORY INVESTIGATION

This appendix includes a discussion of test procedures and results of the laboratory investigation performed by Wahler Associates for Anderson Dam Spillway (Left Training Wall). The investigation program was carried out employing, in most cases, currently accepted test procedures of the American Society of Testing and Materials (ASTM).

Thin wall tube samples used in the laboratory investigation were obtained during the course of the field investigation as described in Appendix A of this report. Identification of each sample is by hole number, sample number, and depth.

The tests discussed in this report include the determination of natural water content and in-place dry density, grain-size distribution, and triaxial shear testing.

1. Natural Water Content and Dry Density

Natural water content and dry density were determined on selected undisturbed tube samples, in conjunction with the triaxial tests. The samples were extruded and visually classified, trimmed to obtain a smooth flat face, and accurately measured to obtain volume and wet weight. After testing, the samples were dried, in accordance with ASTM D2216-80, for a period of 24 hours in an oven maintained at a temperature of 110°C. The dry weight of each sample was then determined and the moisture content and dry density calculated.

2. Grain-Size Distribution

The gradation characteristics of selected samples were determined in accordance with ASTM D422-63. The samples were soaked in water until individual soil particles were separated and then washed on the No. 200 mesh sieve. That portion of the material retained on the No. 200 mesh sieve was oven-dried and then mechanically sieved. The grain-size distribution tests are presented on Figure B-1.

3. Static Triaxial Shear Testing

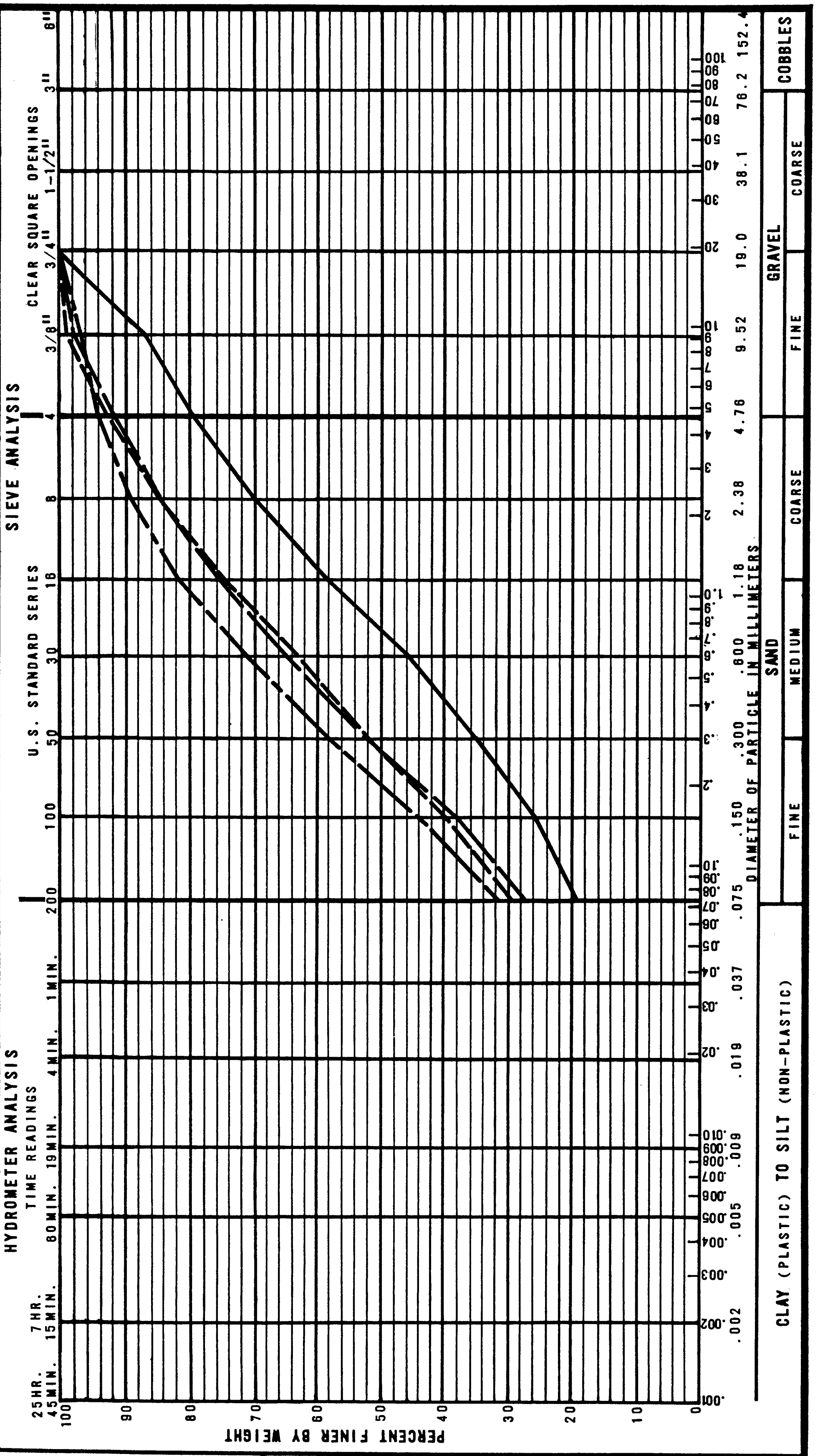
a. Sample Preparation - Samples selected for testing were extruded from the tubes using a hydraulically operated ram capable of exerting the minimum force necessary to free the sample from the tube. The samples were then trimmed to an approximate 2:1 height to diameter ratio. With the aid of a special trimming device which completely supported the sample, the possibility of sample disturbance due to handling was significantly reduced.

After the initial weight and volume measurements were determined, each specimen was placed in a triaxial cell, encased in a latex membrane and sealed to the bottom pedestal and top cap with rubber "O" rings. After securing the triaxial chamber, the cell was filled with water and fitted with a 1-inch-diameter stainless steel piston for load application and transported to the saturation bay.

b. Sample Saturation and Consolidation - The samples were saturated using a combination vacuum-back pressure technique. A small vacuum was applied to increase the initial saturation without a change in void ratio. A back pressure of 50 psi was then incrementally applied to obtain a sufficient degree of saturation prior to the consolidation phase of the test. In order to determine whether the back pressure applied was causing complete saturation, Skempton's "B" parameter was measured for all samples. A value in excess of 0.95 was considered to represent a fully saturated condition. After achieving complete saturation, the chamber pressure was increased above the back pressure to the designated consolidation pressure. The top and bottom drainage lines were then simultaneously opened, and the total volume of water expelled from each sample was monitored as a function of time. Strips of filter paper placed inside the membrane along the sides of the samples accelerated the consolidation process.

c. Sample Failure - The triaxial specimens were failed by compression loading at a constant rate of strain while maintaining a constant minor principal stress. The rate of strain selected for sample failure was dependent upon the materials' consolidation characteristics. Load readings were recorded during the tests at specified axial deformations using a BLH (0-2,000 lb) load cell. Pore pressure measurements were obtained by a Stathom pore pressure transducer (0-200 psi). A two stage failure was performed on one specimen. The adopted failure criterion used for the presentation of the Mohr circle of stress for the triaxial tests was the point of maximum principal effective stress ratio. Results of the triaxial tests appear on Figures B-2 and B-3.

KEY:	———	—·—·—	— — —	—·—·—
LL	----	----	----	----
PL	----	----	----	----
PI	----	----	----	----
NAT. W/C	30.5	24.5	28.7	16.3
SPEC. GRAVITY	----	----	----	----
CLASSIF. SYMB.	SM	SM	SM	SM
SAMPLE NO.	PB-1	PB-5	PB-8 (TOP)	PB-10
DEPTH, FT.	4.0-6.5	13.0-14.2	17.5-20.0	22.4-25
HOLE NO.	DH-1-87	DH-1-87	DH-1-87	DH-1-87



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LEFT TRAINING WALL
ANDERSON DAM SPILLWAY

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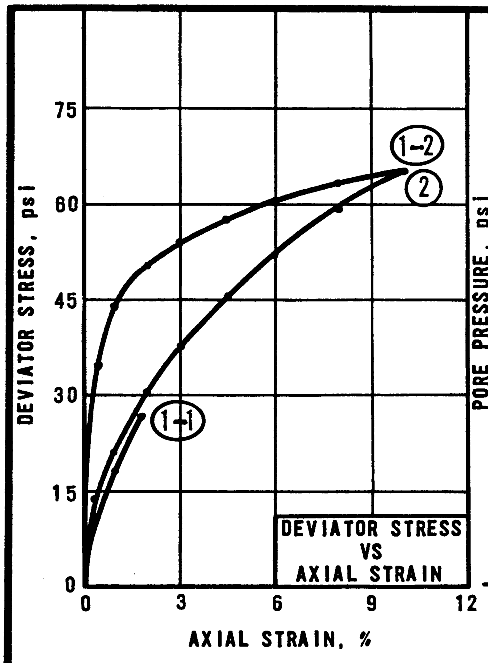
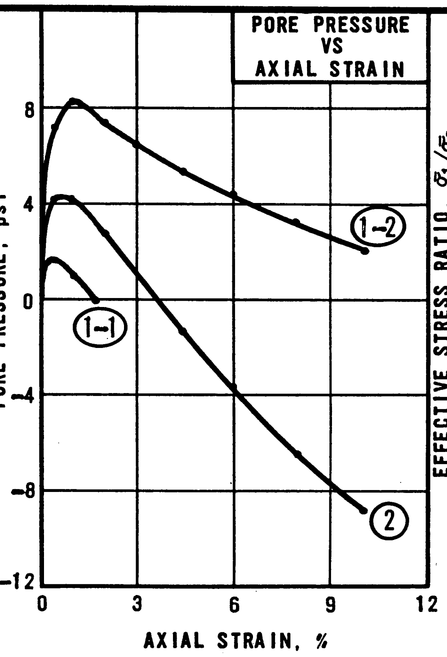
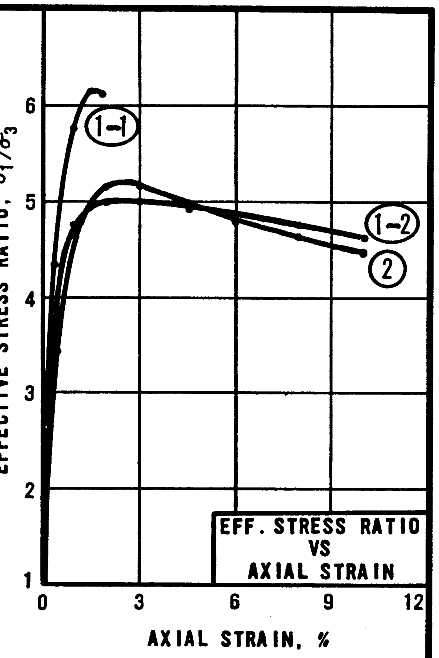
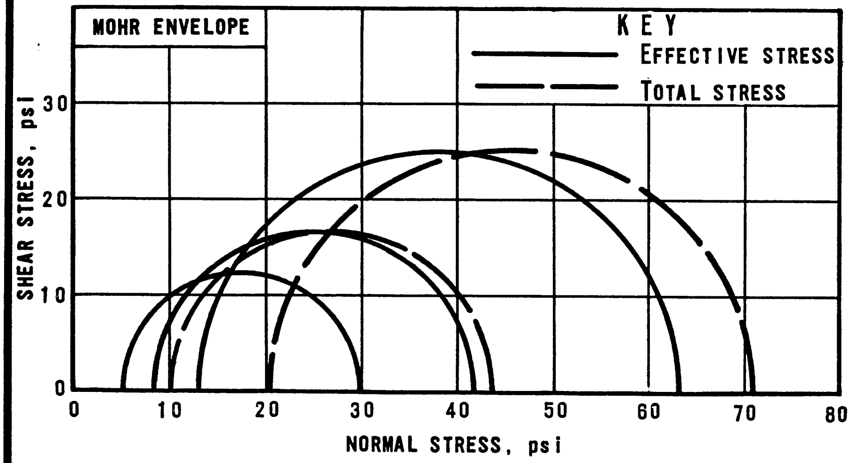
GRADATION TEST RESULTS

PROJECT NO.	DATE	FIGURE NO.
SCV-124C	FEBRUARY 1987	B-1



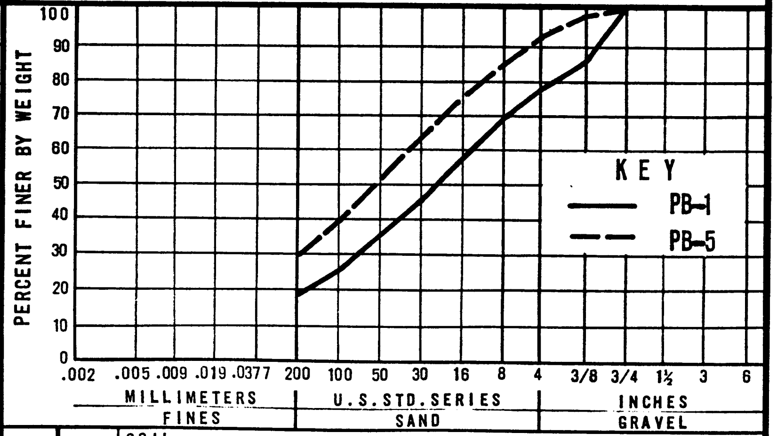






SPECIMEN NO.	CONSOL PRIOR TO SHEAR, %
1-1	0.49
2	1.00
1-2	1.12

	SPECIMEN NO.	①-① (1-1)	② (2)	1-2
INITIAL CONDITION	Water Content,%	30.5	24.5	34.3
	Opt.Water Content,%	----	----	----
	Dry Density,pcf	87.1	96.5	87.5
	Max.Dry Density,pcf	----	----	----
	Void Ratio	0.935	0.745	0.925
	Saturation,%	88	89	100
FINAL CONDITION	Consol.Pressure,psi	5.0	10.0	20.0
	Water Content,%	34.3	27.0	33.5
	Dry Density, pcf	87.5	97.5	88.5
	Void Ratio	0.925	0.728	0.903
	Saturation,%	100	100	100
GENERAL	Specimen Diameter.in	2.875	2.875	2.875
	Back Pressure,psi	50.0	50.0	50.0
	Test Time,hr	0.48	2.55	2.48
	Rate of Strain,%/hr	3.75	3.91	4.01



SYMB	SM	SOIL CLASSIFICATION GRAVELLY SILTY SAND, GRAYISH YELLOW BROWN
LL	----	
PL	----	SAMPLE LOCATION Spec. 1: DH-1-87, PB-1, 4-6.5'
PI	----	Spec. 2: DH-1-87, PB-5, 13-14.2'
SG	2.7 (est.)	NOTE: UNDISTURBED SPECIMENS SPECIMEN 1-2 IS A STAGE TEST OF 1-1.

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LEFT TRAINING WALL
ANDERSON DAM SPILLWAY

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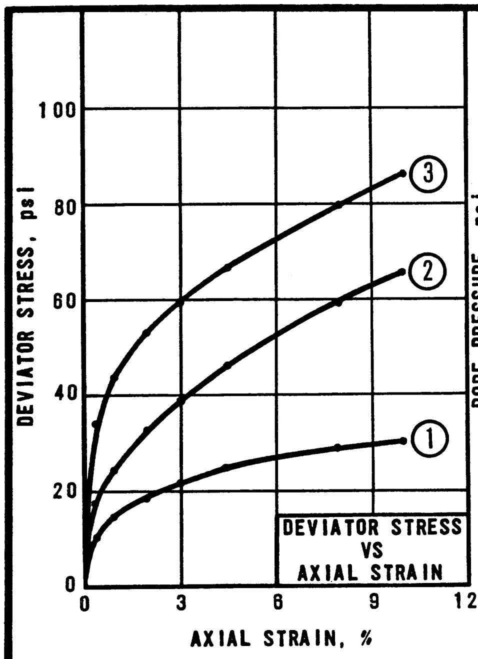
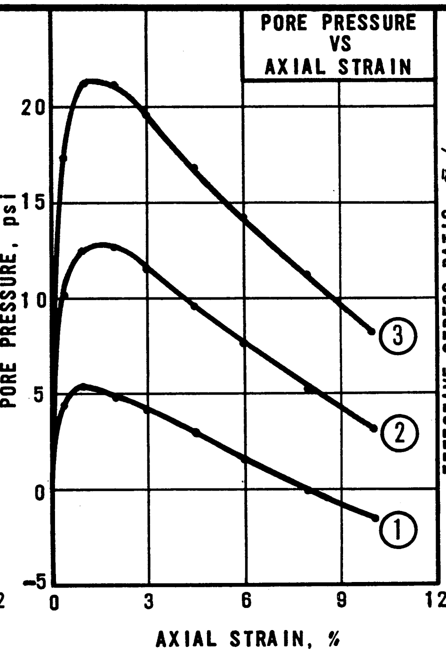
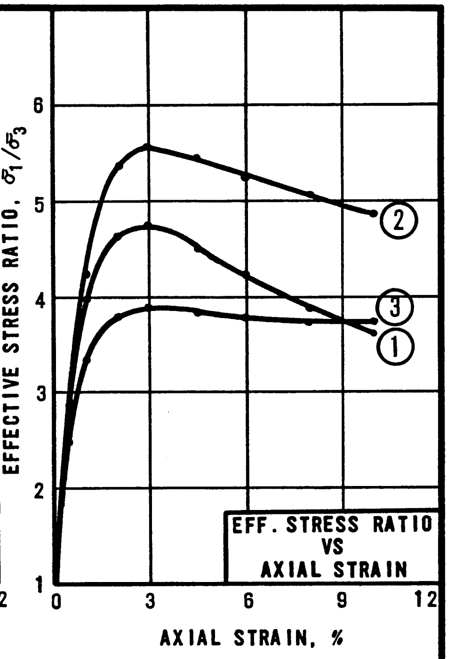
TRIAXIAL TEST RESULTS
CONSOLIDATED UNDRAINED

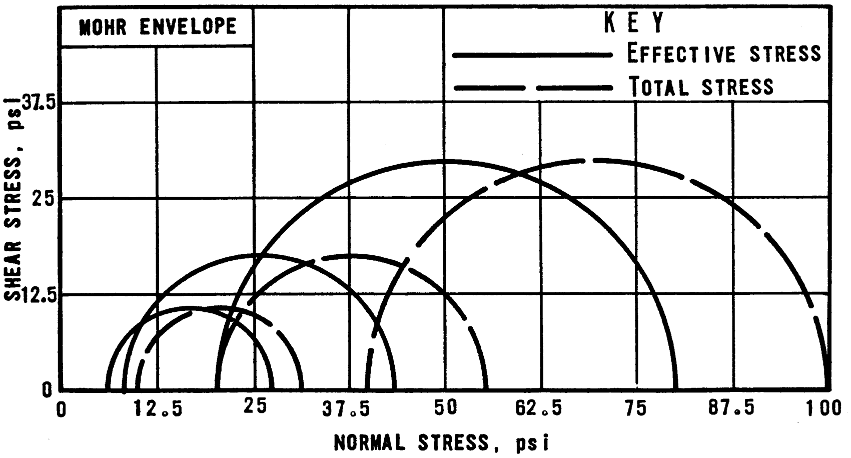
PROJECT NO.	DATE	FIGURE NO.
SCV-124C	FEBRUARY 1987	B-2

HOLE NO., SAMPLE NO.
DH-1-87
PB-1 & 5



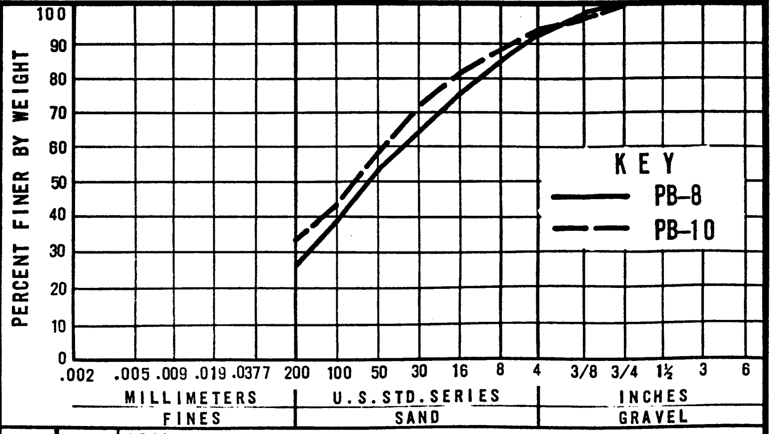






SPECIMEN NO.	CONSOL PRIOR TO SHEAR, %
1	1.41
2	2.35
3	3.54

	SPECIMEN NO.	①	②	③
INITIAL CONDITION	Water Content,%	28.7	21.3	16.3
	Opt.Water Content,%	----	----	----
	Dry Density,pcf	88.6	101.7	110.8
	Max.Dry Density,pcf	----	----	----
	Void Ratio	0.901	0.656	0.521
	Saturation,%	86	88	84
FINAL CONDITION	Consol.Pressure,psi	10.0	20.0	30.0
	Water Content,%	32.4	22.9	17.3
	Dry Density, pcf	89.9	104.2	114.8
	Void Ratio	0.874	0.617	0.467
	Saturation,%	100	100	100
GENERAL	Specimen Diameter.in	2.875	2.875	2.875
	Back Pressure,psi	50.0	50.0	50.0
	Test Time,hr	2.52	2.50	2.53
	Rate of Strain,%/hr	3.97	3.99	3.94



SYMB	SM	SOIL CLASSIFICATION	GRAVELLY SILTY SAND, YELLOW BROWN
LL	----		
PL	----	SAMPLE LOCATION	SPEC. 1 & 2: DH-1-87, PB-8, 17.5-20'
PI	----		SPEC. 3: DH-1-87, PB-10, 22.4-25'
SG	2.7 (est.)	NOTE:	UNDISTURBED SPECIMENS

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LEFT TRAINING WALL
ANDERSON DAM SPILLWAY

PALO ALTO ● CALIFORNIA

TRIAXIAL TEST RESULTS
CONSOLIDATED UNDRAINED

PROJECT NO.	DATE	FIGURE NO.	HOLE NO., SAMPLE NO.
SCV-124C	FEBRUARY 1987	B-3	DH-1-87 PB-8 & 10